8.0 CONCLUSIONS

The primary purpose of this study was to address environmental concerns associated with potential sand dredging from the OCS offshore central east Florida for beach replenishment. Primary concerns focused on physical and biological components of the environment at nine proposed sand resource areas. Physical processes and biological characterization data were analyzed to assess potential impacts of offshore dredging activities within the study area to minimize or preclude long-term adverse environmental impacts at potential borrow sites and along the coastline landward of these sites. The following summary documents conclusions regarding potential environmental effects of sand mining on the OCS for replenishing sand to eroding beaches. Because benthic and pelagic biological characteristics are in part determined by spatially varying physical processes throughout the study area, physical processes analyses were summarized first.

8.1 WAVE TRANSFORMATION MODELING

Excavation of an offshore borrow site can alter incoming wave heights and the direction of wave propagation. Offshore topographic relief causes waves to refract toward the shallow edges of borrow sites. Changes in the wave field caused by borrow site geometry may change local sediment transport rates, where some areas may experience a reduction in longshore transport and other areas may show an increase. The most effective means of quantifying physical environmental effects of sand dredging from shoals on the continental shelf is by applying wave transformation numerical modeling tools that recognize the random nature of incident waves as they propagate onshore. To determine the potential physical impacts associated with dredging at borrow sites offshore central east Florida, spectral wave transformation modeling (STWAVE) was performed for existing and post-dredging bathymetric conditions. Comparison of computations for existing and post-dredging conditions illustrated the relative impact of borrow site excavation on wave-induced coastal processes. Although the interpretation of wave modeling results was relatively straightforward, evaluating the significance of predicted changes for accepting or rejecting a borrow site was more complicated.

As part of any offshore sand mining effort, the MMS requires evaluation of potential environmental impacts associated with alterations to nearshore wave patterns. To determine potential impacts associated with borrow site excavation, the influence of borrow site geometry on local wave refraction patterns was evaluated. Because large natural spatial and temporal variability exists within the wave climate at a particular site, determination of physical impacts associated with sand mining must consider the influence of process variability. A method based on historical wave climate variability, as well as local wave climate changes directly attributable to borrow site excavation, was applied to determine appropriate criteria for assessing impact significance.

From existing conditions model results offshore Cape Canaveral, Canaveral Shoals, the complex of ridges and troughs that extend southeast from Cape Canaveral, caused significant increases in wave height as waves propagated over this area. As 1.0 m, 7.7 sec waves from the east-southeast refracted around the shoals, wave heights increased by 0.5 m over offshore wave conditions. Significant changes in wave direction also were observed in these areas. A greater degree of wave refraction was illustrated for longer period waves. For a 1.6 m, 14.3 sec wave propagating from the east-northeast, wave direction for some nearshore regions adjacent to the Cape changed more than 45 degrees, following the gradient in bathymetric contours. Largest waves in the model domain occurred at shoals northeast of Port Canaveral (1.3 m higher than offshore waves). At shoals in the vicinity of the borrow site in Area A1, wave heights increased to a maximum of 2.8 m, 1.2 m above offshore conditions. Shoals tended to refract wave energy and caused focusing (wave convergence) near the Cape. However, the coast south of the Cape illustrated reduced wave heights (wave divergence).

Post-dredging wave height changes offshore Cape Canaveral illustrated a maximum wave height increase of 0.2 to 0.7 m and maximum wave height decrease in the shadow zone of the site of 0.3 m. The overall area of influence for the borrow site in Area A1 extended approximately 14 km north of the Cape to about 4 km south of Port Canaveral. The area of greatest wave height increase occurred at the northwest corner of the site. Wave heights did not increase by the same amount at the southwest corner, likely due to local bathymetry and geometry of the site. Deeper excavation depths at the northwest corner cause a greater degree of wave refraction. However, for all wave simulation cases, the impact of borrow site excavation on wave height and direction changes was minor relative to natural variability of the local wave climate and transport regime.

Wave model output for waves propagating from the NNE, offshore Sebastian Inlet at borrow sites in Areas B1 and B2, illustrated minor changes throughout the model domain. The shoal encompassing the borrow site in Area B1 had the greatest influence on wave propagation in the region, although effects were small because the shoal had a minimum depth of approximately 12 m NGVD. Changes in the wave field caused by dredging at borrow sites in Areas B1 and B2 illustrated minor impacts for the Area B model domain. For 1.9 m, 6.9 sec waves propagating from the NNE, borrow sites had a limited influence on waves over a long section of coast (>30 km), but changes on the order of 0.01 m occurred along 2.5 km of coast landward of the borrow site in Area B1. Maximum change in wave height was approximately 0.10 m at Area B1 and 0.12 m at the borrow site in Area B2. The length of shoreline influenced by changes in wave propagation for 1.7 m, 10.8 sec waves propagating from the north-northeast from the two borrow sites was approximately 20 km; however, greatest changes occurred within a 12 km stretch of coast. At Area B1, maximum changes in wave height were 0.13 m, very similar to those computed for the borrow site in Area B2. However, for all wave simulation cases offshore Sebastian Inlet, the impact of borrow site excavation on wave height and direction changes was minor relative to natural variability of the local wave climate and transport regime.

For the wave model domain offshore St. Lucie Inlet, 1.5 m, 7.5 sec waves propagating from the northeast illustrated slight wave focusing at shoals within the designated borrow site boundaries. The minimum depth at Site C1 north was 7.6 m NGVD, and 5.4 m NGVD was the minimum depth at Site C1 south. Because shallower depths exist in these areas, waves passing over the shoals refracted toward the shoreline sooner than in other areas the same distance offshore. For C1 north, maximum wave height increase was 0.18 m, and the maximum decrease was 0.39 m. Similar changes occurred at C1 south, where the maximum increase in wave height was 0.13 m and the maximum decrease was 0.33 m. For 1.1 m, 11.1 sec waves from the east, wave height changes at C1 north and C1 south were not as large as those for Case 2C, but wave energy was still focused behind the shoals. This focusing caused a zone of increased wave heights that extended to the shoreline.

For post-dredging conditions, wave height differences resulting from dredging Sites C1 north and C1 south indicated a strong interaction between the two sites because C1 south was partially within the shadow zone of C1 north. The alignment of borrow sites caused a single area of increased wave heights at the shoreline (approximately 4 km long) and a more diffuse zone of reduced wave heights (extending 12 km south toward St. Lucie Inlet). Similar results were found for longer period waves from the east, where wave height differences illustrated that the borrow sites have an overlapping influence at the shoreline, even though one site was not directly in the shadow of the other. For these longer period waves, the total length of affected shoreline was approximately 16 km, and changes at borrow sites were similar in magnitude to waves from the northeast.

The primary bathymetric feature impacting wave propagation in modeled Area D is located approximately 5.6 km offshore Jupiter Inlet. The shoal has a minimum water depth of 11.7 m NGVD, and the borrow site in and adjacent to Area D2 lies along the seaward margin of the shoal at the Federal-State boundary. For 1.4 m, 6.9 sec waves from the NNE, the shoal produced a slight focusing of waves seaward of the shoal and an area of reduced wave heights 2.6 km along the shoreline north of Jupiter Inlet. Similar results were documented for 1.3 m, 13.0 sec waves from the ENE. Wave heights increased behind the shoal, and a 4.9 km stretch of coastline north of Jupiter Inlet experienced increased wave heights.

Wave height changes resulting from dredging Borrow Site D2 showed greatest change at the north end of the site where the deepest excavation occurred. The maximum increase and decrease in wave height that resulted for waves from the north-northeast was 0.04 and 0.05 m, respectively. This small change relative to changes at borrow sites to the north was due to greater water depths at and seaward of the borrow site. Overall, wave simulation cases offshore Jupiter Inlet illustrated minor wave height and direction changes in response to borrow site excavation relative to natural variability of the local wave climate and transport regime.

8.2 CIRCULATION AND SEDIMENT TRANSPORT DYNAMICS

Current measurements and analyses and wave transformation modeling provided baseline information on incident processes impacting coastal environments under existing conditions and with respect to proposed sand mining activities for beach replenishment. Ultimately, the most important data set for understanding physical processes impacts from offshore sand extraction is changes in sediment transport dynamics resulting from potential sand extraction scenarios relative to existing conditions.

Circulation patterns along the central east Florida coast near potential offshore borrow sites were investigated using current meter observations obtained offshore St. Lucie Inlet and over Thomas Shoal, seaward of Sebastian Inlet. Analysis of historical data indicated that circulation patterns consisted predominantly of along-shelf currents that reversed direction approximately every 2 to 10 days. Current reversals were found weakly correlated with local wind stress; literature suggested that subtidal variability was due to meanders or spin-off eddies of the Florida Current. Peak speeds were on the order of 40 to 50 cm/sec at mid-shelf and inner-shelf locations and were directed either upshelf (to the north-northwest) or downshelf (to the south-southeast). Strongest currents were most commonly directed to the north. Tidal currents contributed significantly to inner-shelf current observations; however, these observations were obtained near the tidally-dominated St. Lucie Inlet and may not be reflective of inner shelf regions removed from major coastal inlets.

ADCP measurements in the vicinity of Thomas Shoal offshore Sebastian Inlet also were dominated by along-shelf flows that correlated with seasonal changes in wind. May survey conditions were dominated by winds from the south, while September survey conditions were characterized by short wind events from the north. Current measurements illustrated a mean flow directed to the north during spring and to the south in fall. This seasonal directionality of flow was supported by historical data and literature regarding observations on the mid-shelf and inner-shelf where sand resource areas have been identified. Strongest currents flowed to the south at 30 cm/sec during the September survey in response to northerly winds.

In shallow waters, over shoals and adjacent to tide-dominated inlets such as St. Lucie, cross-shelf tides may influence current velocities. May and September field data showed onshore currents dominated across the shoal. During the May survey, onshore currents were enhanced by flood tide. Tidal dependence was not observed during the September survey. On the inner- to mid-shelf, in the vicinity of the sand resource areas, tidal effects are secondary to wind effects. In the presence of local bathymetric features, such as Thomas Shoal, steering and sheltering of flow across the shoal were observed. Under average conditions, currents were steered onshore across the shoal. In the presence of dominant winds, near-bottom currents flowed parallel to bathymetric contours.

The analysis of current patterns resulting from this study suggests proposed sand mining will have negligible impact on large-scale shelf circulation. The proposed sand mining locations are small relative to the entire shelf area, and it is anticipated that resulting dredging will not remove enough material to significantly alter major bathymetric features in the region. Therefore, the forces and/or geometric features that principally affect circulation patterns are expected to remain relatively unchanged.

Three independent sediment transport analyses were completed to evaluate physical environmental impacts due to sand mining. First, historical sediment transport trends were quantified to document regional, long-term sediment movement throughout the study area using historical bathymetric data sets. Erosion and accretion patterns were documented, and sediment transport rates in the littoral zone and at offshore borrow sites were evaluated to assess potential changes due to offshore sand dredging activities. Second, sediment transport patterns at proposed offshore borrow sites were evaluated using wave modeling results and current measurements. Post-dredging wave model results were integrated with regional current measurements to estimate sediment transport trends for predicting borrow site infilling rates. Third, sediment transport was predicted using wave modeling output to estimate potential impacts to the longshore sand transport system (beach erosion and accretion). All three methods were compared for documenting consistency of measurements relative to predictions, and potential physical environmental impacts were identified.

8.2.1 Historical Sediment Transport Patterns

Regional geomorphic changes between 1877/83 to 2002 were analyzed for assessing long-term, net coastal sediment transport dynamics. Although these data did not provide information on potential impacts of sand dredging from proposed borrow sites, they did provide a means of verifying predictive sediment transport models relative to infilling rates at borrow sites and longshore sand transport.

Shoreline position and nearshore bathymetric change documented four important trends relative to study objectives. First, the predominant direction of sediment transport on the continental shelf and along the outer coast between Cape Canaveral and Jupiter Inlet was north to south. The greatest amount of shoreline change in this study was associated with beaches adjacent to Cape Canaveral, Port Canaveral Entrance, and beaches south of St. Lucie Inlet. Second, the most dynamic features within the study area are the beaches and shoals associated with Cape Canaveral. Areas of significant erosion and accretion reflect wave and current dynamics and the contribution of littoral sand transport from the north to shoal and spit migration. Depositional zones also were prominent in the shoal regions along the inner shelf from Fort Pierce south to Jupiter Inlet. Large quantities of carbonate and shell fragments observed in sediment samples collected from shoals in this region indicated that much of the deposition in this portion of the study area may have been locally produced.

Third, alternating bands of erosion and accretion documented between 1956 and 1996 offshore Cape Canaveral illustrated steady reworking of the upper shelf surface as sand ridges migrated from north to south. The process by which this was occurring at Area A1 suggested that the borrow site in this region would fill with sand transported from the adjacent seafloor at rates ranging from 88,000 to 119,000 m^3/yr. Areas of erosion and accretion documented between 1929/31 and 1929/73 between Port Canaveral Entrance and Jupiter Inlet indicated the amount of sediment available for infilling sites south of Port Canaveral Entrance was between 38,000 and 113,000 m^3/yr.

Finally, net longshore transport rates determined from seafloor changes in the littoral zone between Cape Canaveral and Port Canaveral Entrance, in conjunction with dredging records for Port Canaveral entrance, indicated maximum transport rates near Cape Canaveral, with lower rates south of the entrance. Net longshore transport at Port Canaveral entrance was estimated at about 236,000 m^3/yr. South of the Port, rates have been estimated to range from 119,000 m^3/yr immediately south of the entrance to 140,000 to 184,000 m^3/yr between Fort Pierce and Jupiter Inlets.

8.2.2 Sediment Transport at Potential Borrow Sites

In addition to predicted modifications to the wave field, potential sand mining at offshore borrow sites resulted in minor changes in sediment transport pathways in and around potential dredging sites. Modifications to bathymetry caused by sand mining only influenced local hydrodynamic and sediment transport processes in the offshore area. Although wave heights changed at the dredged borrow sites, areas adjacent to these sites did not experience dramatic changes in wave or sediment transport characteristics.

Initially, it is anticipated that sediment transport at borrow sites will occur rapidly after sand dredging is completed. For water depths at the proposed borrow sites, minimal impacts to waves and regional sediment transport are expected during infilling. The characteristics of sediment that replaces borrow material during infilling will vary based on location, time of dredging, and storm characteristics following dredging episodes. Average computed infilling rates ranged from a minimum of about 5,000 m^3/yr (Site D2) to a high of about 538,000 m^3/yr (Site A1), while the infilling time varied from 25 to >500 years. Site A1 had the greatest infilling rate due to its shallow water depth relative to the other sites and its large perimeter. Because Site A1 is in shallow water, wave-induced and wind-driven currents were larger than at deeper sites, and more sediment was mobile in the proximity of the borrow site. Furthermore, sites that have a larger surface area generally trap more sediment in a given time period. Estimated infilling rates and times are most useful as a relative guide for borrow site infilling rather than an absolute indicator of exactly how long it takes for the borrow site to fill. The analysis performed provided a reasonable estimate of infilling times for resource management purposes.

8.2.3 Nearshore Sediment Transport Modeling

Comparisons of average annual sediment transport potential were performed for existing and post-dredging conditions to indicate the relative impact of dredging to longshore sediment transport processes. The significance of changes to longshore transport along the modeled shoreline resulting from dredging proposed borrow sites to their maximum design depths was determined using the method described in Kelley et al. (2004).

Mean sediment transport potential calculated for the shoreline south of Port Canaveral indicated strong net southerly transport of approximately 500,000 m^3/yr, which gradually reduced to approximately 300,000 m^3/yr south of Indialantic Beach. The transport significance envelope was largest (approximately $\pm$300,000 m^3/yr) north of Cape Canaveral and near Indialantic Beach. Model output for the region south of Cape Canaveral indicated that the significance envelope was approximately 20% of the mean computed net transport potential in the area of greatest impact from the borrow site in Area A1. The maximum modeled decrease in south-directed transport for post-dredging conditions was about a 40,000 m^3/yr (within the transport significance range), just south of Port Canaveral.

Mean transport potential computed adjacent to Sebastian Inlet indicated that net transport potential was generally less than 100,000 m^3/yr to the south, with an approximate $\pm$500,000 m^3/yr range in net transport potential. Computations indicated that it was possible in some years for net transport potential to be northward directed. Near Vero Beach, net transport potential was to the south at around 500,000 m^3/yr and annual variation in net transport potential was similar (approximately $\pm$500,000 m^3/yr). This may be due to a change in shoreline orientation that occurred at this point. The transport significance range for computed mean transport rates was nearly consistent at about $\pm$100,000 m^3/yr. The largest calculated differences between existing and post-dredging transport potential occurred north of Sebastian Inlet (where the transport rate becomes more southerly by 30,000 m^3/yr) and just south of the inlet (where transport rates become less southerly by 30,000 m^3/yr), indicating that Sites B1 and B2 would not produce significant modifications to coastal processes along the shoreline.

Computed mean annual transport potential for the beaches just north of St. Lucie Inlet was to the south, ranging from approximately 400,000 m^3/yr at the northern extent of the grid to approximately 100,000 m^3/yr at the southern limit near St. Lucie Inlet. Annual variability in transport potential had a range of approximately $\pm$400,000 m^3/yr to the north that gradually decreases to approximately $\pm$200,000 m^3/yr at the southern limit of the modeled area. Along some sections of the modeled shoreline, it was possible to have net northerly-directed transport during some years. For Borrow Sites C1 north and C1 south (north of St. Lucie Inlet), the computed longshore transport significance range was approximately $\pm$100,000 m^3/yr at the northern limit of the area and $\pm$50,000 m^3/yr at the southern limit. Potential impacts from dredging these sites to a maximum excavation depth of 12 m NGVD indicated that the significance envelope was exceeded along a 2-km length of shoreline approximately 18 km north of St. Lucie Inlet. At the point of maximum dredging-induced change along the shoreline, the significance level was ±60,000 m^3/yr, and the computed change in transport potential was 85,000 m^3/yr. As such, the proposed borrow site configuration may not be acceptable. If a borrow site redesign were required, the most likely change would be a reduction in maximum dredging depth to reduce site impacts.

Net transport along the coastline adjacent to Jupiter Inlet varied from about 200,000 m^3/yr to the south near the northern limit of the area to about 500,000 m^3/yr to the south near Jupiter Inlet. Annual transport variability ranged from approximately ±150,000 m^3/yr in the northern part of the area to approximately ±300,000 m^3/yr at the southern extent of the model grid. As with the entire study area south of Cape Canaveral, net transport potential was always to the south and transport variability was large. The envelope of significant change in potential longshore transport rates under natural wave propagation conditions for Borrow Site D2 (offshore Jupiter Inlet) ranged from approximately ±50,000 m^3/yr in the north to ±100,000 m^3/yr in the south, with a maximum of approximately ±150,000 m^3/yr occurring just north of Jupiter Inlet. Modeled dredging impacts to transport potential for Site D2 were minimal; predicted changes were well within the transport variability significance range. Small impacts for this area (compared with previous modeled areas) resulted from larger borrow site depths, smaller excavation volume, and the sheltering effect of the shoal landward of D2.

Overall, it was determined that no significant changes in longshore sediment transport potential would result from modeled borrow site configurations for Areas A, B, and D. However, the proposed sites in Area C do have significant impacts to transport potential along the shoreline. Therefore, Area C sites should be redesigned so impacts are within acceptable limits, most likely by reducing the maximum depth of excavation at the sites.

8.3 BENTHIC ENVIRONMENT

Results of the biological field surveys agree well with previous descriptions concerning benthic assemblages associated with shallow areas offshore east Florida. Benthic assemblages surveyed from the sand resource areas consisted of members of the major invertebrate and vertebrate groups commonly found in the general area.

Numerically dominant infaunal groups included numerous crustaceans, mollusks, and polychaetes. Canonical discriminant analysis indicated that the composition of infaunal assemblages was affected primarily by sediment type and secondarily by survey. Distributions were affected mostly by the amount of very fine sediments in benthic grabs, primarily silts and to a lesser degree clays. Very few infaunal taxa in this study were distributed across a broad sedimentary regime. Most species were restricted to stations with varied amounts of measurable fines, measurable gravel, or pure sand. Stations with measurable gravel yielded the greatest numbers of infauna. Species richness and individual abundance values were greater in September than June because of seasonal recruitment patterns. Between-survey differences at stations with measurable gravel were due primarily to the September presence of species that were largely or completely absent in June samples. Finer sediments, including sand stations and stations with measurable mud, had similar infaunal composition across surveys. Sand stations yielded burrowing amphipods during both field surveys. Between-survey differences at muddy sand stations were due to more abundant mud-dwelling infauna in September samples.

In addition to sedimentary habitat and survey month, discriminant analysis indicated that infaunal assemblage differences between stations were correlated somewhat with water depth. Shallowest stations in the study yielded similar assemblages. Deeper stations in Areas D1 and D2 were delineated as a group in the cluster analysis, despite differences with respect to sediments. The proximity of the Gulf Stream to the southern portion of the study area may have influenced the infaunal community in this area.

Epifauna consisted primarily of decapods. Sand dollars and squids also were prominent in trawls. During September, 90% of all epifaunal individuals were collected from Areas A1, A2, and A3. Epifaunal taxa were heterogeneously distributed during June, except for *E. michelini* and spider crab that were collected from multiple stations. These between-survey differences in epifaunal distribution are likely due to seasonal changes in water temperature, known to be a primary environmental regulator of the distributions of motile epifaunal populations.

Fishes collected by trawling in the nine sand resource areas reflected the transitional regional species pool of east-central Florida that includes a complex of tropical, subtropical, and warm temperate taxa. Although most species collected in the sand resource areas were typical soft bottom forms such as drums, flatfishes, and searobins, some hard bottom species were collected in Area D1. There were considerable differences in the composition, diversity, and numbers of fishes caught by trawling during the September and June surveys, particularly in northern Areas A1, A2, A3, and B1, reflecting seasonal trends in the occurrence and abundance of fishes in the South Atlantic Bight. Fishes collected were common members of the regional ichthyofauna, exhibiting expected spatial and temporal patterns in their distribution.

Effects of dredging on soft bottom fishes would include turbidity and disruption of benthic prey base utilized by many demersal species. Fishes are likely to avoid highly turbid areas and would respond in species-specific fashion to changes in the benthic invertebrate assemblages.

Potential benthic effects from dredging will result from sediment removal, suspension/dispersion, and deposition. Effects on infaunal populations primarily will occur through removal of individuals along with sediments. Effects are expected to be short-term and localized. Seasonality and recruitment patterns indicate that removal of sand between late fall and early spring would result in less stress on benthic populations. Early-stage succession will begin within days of sand removal, through larval recruitment dominated by opportunistic taxa, especially polychaetes such as *Mediomastus* and *Paraprionospio pinnata* and bivalves such as *Tellina agilis*. These species are adapted to environmental stress and exploit suitable habitat when it becomes available. Later successional stages of benthic recolonization will be more gradual, involving taxa that generally are less opportunistic and longer lived. Immigration of motile annelids, crustaceans, and echinoderms into impacted areas also will begin soon after excavation.

While community composition may differ for a period of time after the last dredging, the infaunal assemblage type that exists in mined areas will be similar to naturally occurring assemblages in the study area, particularly those assemblages inhabiting inter-ridge troughs. Based on previous observations of infaunal reestablishment, and assuming that dredged sites do not create a sink for very fine sediments or result in hypoxic or anoxic conditions, the infaunal community in dredged sites most likely will become reestablished within 2 years, and will exhibit levels of infaunal abundance, diversity, and composition comparable to nearby nondredged areas. Given that the expected beach replenishment interval is on the order of a decade and that the expected recovery time of the affected benthic community after sand removal is anticipated to be much less than that, the potential for significant cumulative benthic impacts is remote.

Hard bottom habitat was surveyed and described in Areas B1, D1, and D2 and near C2. Epibiota and demersal fish assemblages associated with hard bottom were typical for the region. From a qualitative perspective, octocoral density and taxonomic richness was higher in the southern Areas D1 and D2 than the northern Areas B1 and C2 and algal cover was more prevalent in the northern areas. These trends indicate that natural environmental factors (water temperature, clarity, and circulation) influence the composition of epibiotal assemblages on a broad scale (kilometers) along the east coast of Florida. These observations suggest that epibiotal assemblages in the southern areas would take longer time to recover from mechanical impacts associated with sediment removal and would be more sensitive to sediment resuspension and deposition than would assemblages north of Areas D1 and D2.

8.4 PELAGIC ENVIRONMENT

Pelagic fishes such as bluefish, cobia, jack crevalle, and king and Spanish mackerels are important economically and ecologically in eastern Florida shelf waters and could be susceptible to impacts associated with dredging. Dredge-related turbidity can divert pelagic fishes from normal migratory routes, feeding grounds, or spawning areas. Structures and vessels may attract pelagic fishes for various reasons and in doing so also divert them from regular migratory routes. Noise from working dredges could affect pelagic fishes attracted to the structures. Despite the possibility of these effects on pelagic fishes, dredging at the central east Florida sand borrow sites is not likely to adversely affect pelagic fish populations unless specific spawning, aggregation, or migratory areas are disrupted. The limited spatial and temporal scale of dredging projects expected for the sand resource areas would lessen the severity of any potential effects.

Essential fish habitat for managed species occurring in the study area broadly includes the water column as well as soft and hard bottom substrates. Managed species or species groups occurring in the project area are penaeid and rock shrimps, golden crab, spiny lobster, corals, coral reefs, and hard/live bottom areas, red drum, coastal pelagic fishes, reef fishes (snapper-grouper management unit), highly migratory species, and *Sargassum*. Although some of these species or groups do not normally inhabit the sand resource areas, most of them will traverse the water column as planktonic early life stages. Dredging could affect small segments of the habitats and species in the sand resource areas through mechanical damage of hard bottom, sediment suspension and turbidity, and direct burial of organisms or habitats. The magnitude of these effects is generally expected to be small due to the relatively small spatial and temporal scales encompassed by dredging projects. Nevertheless, careful management of dredging operations should be undertaken to ensure that impacts from routine operations and accidents do not adversely impact EFH or managed species within the study area.

The main potential effect of dredging on sea turtles is physical injury or death caused by the suction and/or cutting action of the dredge head. No significant effects on turtles are expected from turbidity, anoxia, or noise. Of the five sea turtle species that typically occur off Florida (loggerhead, green, hawksbill, Kemp's ridley, and leatherback), all except the leatherback are considered to be at risk because of their benthic feeding habits.

Loggerheads are the most abundant turtles in the study area, and historically, they have been the species most frequently entrained during hopper dredging. If a hopper dredge is used, then it would be best to avoid operations during the period that corresponds with their nesting season inshore of the study area (April through September). This same period would generally have higher risk of encountering nesting green and hawksbill turtles and juvenile and subadult Kemp's ridley turtles. If use of a hopper dredge during this season cannot be avoided, then other mitigation and monitoring requirements may be appropriate, such as turtle monitoring and use of a turtle-deflecting draghead. If a cutterhead suction dredge is used, seasonal or other restrictions are considered unnecessary because there is little likelihood of killing or injuring sea turtles.

Marine mammal species occurring commonly on the shelf, such as bottlenose dolphin and Atlantic spotted dolphin, may be present year-round but are unlikely to be adversely affected by dredging due to their agility and the unrestricted, open ocean environment where operations are planned. Northern right whales occur as seasonal residents during winter and spring (December through March). Humpbacks are only occasional strays from the main migrating population during winter months. Generally, the probability of encountering these species in the study area would be lowest during summer. It is then likely that seasonal restrictions on dredging and other measures to minimize possible vessel interactions with endangered whales may be required by the NMFS.